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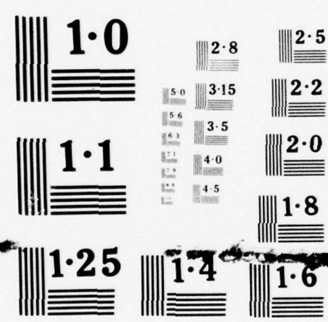
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Monterey, California

THESIS

CONSIDERATION OF THE CARRIER-BASED TACTICAL SUPPORT CENTER INSTALLATION DESIGN

by

Stanley Dean Arnote

March 1977

Thesis Advisor: D. E. Neil

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20. Abstract (Cont'd)

CV-TSC aboard the USS Constellation (CV-64) and general recommendations for all CV-TSC installations.

Consideration of the Carrier-Based Tactical Support Center Installation Design

by

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Lieutenant, United States Navy
B.S., University of Missouri, 1969

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY

from the
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March 1977

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ABSTRACT

This thesis analyzes the aircraft carrier based Tactical Support Center (CV-TSC) installation design from a human factors viewpoint. Starting with the threat, the mission of the CV-TSC is defined. A modular concept between man and machine is developed. Man's role, tasks, and functions are identified and form the basis for recommended changes to the CV-TSC aboard the USS Constellation (CV-64) and general recommendations for all CV-TSC installations.

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND INFORMATION

1. The Threat and How the United States Meets It

The Soviet war machine has always run on the premise of "defense of the homeland." Being a very large country, with thousands of miles of borders which are easy entry ways for invading forces, the Soviet army has been the main line of defense. With the invention of the submarine, the Soviet first line of defense became the diesel electric submarine. Forced to operate close to its home port because of its limited range, its mission was to sink the enemy threat before they could land on the "homeland" itself, with the Soviet army standing by to destroy those that did make it through the submarine line of defense. [7, 8]

With the Soviets facing the threat of the United States strike attack aircraft carriers (CVA), this mission to sink the enemy became even more imperative. However, hampered by the short ranges of diesel electric submarines, carriers could launch their attack outside the range of the Russian submarine force.

With the invention of nuclear powered submarines the capabilities and mission of the Soviet submarine force

changed drastically. Two basic missions emerged from this vast increase in endurance and speed for the submarine.

The first mission was that of the ballistic missile carrying submarine, with the missile pretargeted for designated areas in the United States and her allies. With the limitation of targeting procedures for these missiles, they were of no threat to operational forces at sea, but could only be targeted for stationary known positions.

The second mission, which had always concerned the Soviets, was stopping the invading enemy. The nuclear powered submarine posed a much more awesome threat than the diesel electric submarine. With its virtually unlimited range, the nuclear submarine could now leave its home waters and attack the enemy at a much greater range and, preferably, long before the enemy was within striking distance of the homeland. [8, 17]

The United States Navy was now faced with an ocean-wide threat to its CVA's from the Soviet submarine force. However; this threat could still easily be met because of the limitation on submarine armament, the torpedo.

Due to limited ranges of torpedoes, the submarine was still forced to come in very close to the target before launching its torpedoes. Merely screening the CVA with sonar equipped destroyers made the submarine susceptible

to detection and attack. The destroyers could easily handle the submarine threat and the difference between nuclear and diesel electric powered submarines was almost negligible.

In the 60's the development of a missile launched by a submarine dramatically extended its attack range. To insure the CVA's safety, the U.S. was forced to "sanitize" a greatly expanded circle around the carrier, keeping it clear of Soviet submarines. This circle has grown so large that sonar equipped destroyers are unable to "sanitize" the area and are themselves vulnerable to the submarines' launched missile attack.

The United States needed a platform capable of operating not only at close-in ranges, as the sonar equipped destroyers had done, but also at long ranges so as to be able to counter the Soviet threat as the range of their missiles grew progressively longer.

Even though the enemy threat had grown, the carrier's ability to defend itself was limited. To carry out its mission, it required certain numbers of aircraft, with prescribed capabilities in regards to armament and mission capability. Due to the physical limitation imposed by available deck space on a carrier, there was little if any space available for ASW aircraft. However, with the development of the F-14 aircraft, fewer of them were required for the

same fire power as the F-4's they were replacing. Thus, somewhat alleviating the critical deck space limitation that is inherent in an aircraft carrier, room was made on board for several aircraft dedicated to ASW.

The S-3 aircraft was designed to fill the need for ASW dedicated aircraft to carry out the mission against the threat. It is a high speed, jet powered aircraft with a long on-station time and is capable of detecting, classifying, attacking, and destroying enemy submarines without any outside assistance. Due to the high data rate of modern ASW, the S-3 is only able to accomplish its goal with the use of an on-board, automated digital system. Outside assistance however, may be a valuable asset and can be well utilized by the S-3. [6]

B. THE CV-TSC

The CV-TSC was designed in response to the latest generation of ASW weapons system, such as the S-3, which require computer handling of a high data rate system. With the advent of high data rate requirements, ASCAC facilities were obsolete and the CV-TSC fills this void.

1. Definitions

Reference 12 defines the following as they are treated in this thesis.

"Mission: A statement of what the system is to do to solve a given problem and when and where.

Requirement: A statement of an obligation the system must fulfill to effect the system mission. (ie. further delineation of the mission.)

Function: A general means or action by which the system fulfills its requirements. They are the first hows of the system."

2. CV-TSC Mission

Reference 2 states the mission of the CV-TSC as follows. "The CV-TSC's mission is to provide preflight, inflight, and postflight ASW support to the task force commander and the ASW airborne platforms assigned to the task force."

The task force commander's needs are (1) Plans to accomplish tactical mission objective, (2) Information concerning the present situation, (3) History of prior activities, (4) Postflight analysis. [2]

3. Requirements

To fulfill the role placed on it, the CV-TSC must be able to interface with other high speed data rate digital equipment, and to also communicate with personnel both on the CV and those off the CV such as flight crews. The CV-TSC

must also be able to rapidly process acoustic data both in real time and faster than real time for recorded events.

4. CV-TSC Functions and Tasks

The formulative idea behind the CV-TSC is that we must use "computers" to handle the large amounts of sophisticated data in a timely manner so as to be able to meet the threat on a continually effective basis.

Reference 2 delineates the three basic functions of the CV-TSC with relation to ASW airborne platforms.

a. Preflight Tasks

In order to perform the preflight function, (ie. mission planning) the CV-TSC personnel must accomplish the following tasks:

1. Normal Administrative Procedures - equipment activated and functioning properly and personnel available to operate the equipment.

2. Data Gathering - CV-TSC personnel must gather data from many areas of the CV (Navigation, Operations, Flight Operation, Intelligence, Air Wing Commander, etc.) and change this raw data into a format the digital equipment can work with. Then it must organize its information into a concise and clear form the aircrew can work with.

3. Lines of Communication - actions and procedures required of CV-TSC personnel to transmit the data to

the flight crew and to the computer cassettes onboard the S-3 aircraft.

b. Inflight Tasks

Inflight operations are the most complex area assigned to the CV-TSC because information must be cleared through the appropriate chain of command before it can be disseminated to the airborne flight crew and aircraft.

1. Normal Administrative Procedures - equipment activated and functioning properly and personnel available to operate the equipment.

2. Lines of Communication - messages must flow promptly and accurately either to or from higher authority, ASW platforms, and other support ASW assets.

3. Evaluation - tactical data from all sources such as NTDS, JEZEBEL/DIFAR, etc. must be analyzed and compared to intelligence information in order to reach decisions based on tactical information.

4. Command and Control - recommendations which result from decisions based on evaluation are then forwarded to ASW assets and or tactical commander.

c. Postflight Tasks

Postflight functions include debriefing the aircrew, and collecting the Data Insertion Tape (cassette) for analysis and information transfer to the TSC.

The following tasks are included in postflight functions:

1. Normal Administrative Procedures - equipment activated and functioning properly and personnel available to operate the equipment.

2. Lines of Communication - information flow between aircrew and TSC personnel, cassette and TSC personnel.

3. Debrief - actions required of TSC personnel to obtain pertinent information from aircrew personnel concerning events that happened during their mission.

4. Evaluation - cassette played back and grams and mission events analyzed by TSC personnel.

5. Transmit - actions required to forward evaluated information to higher authority.

II. SYSTEM COMPONENTS

Although the purpose of this study is to analyze the mission of the TSC and to establish a recommended installation pattern for the TSC watch space, in order to facilitate the timely completion of the mission, a description of the system is made to convey an idea of the system layout and the way it functions.

Some assumptions have been made to facilitate the study. Although the system is capable of supporting S-3 aircraft, and helicopters, and can coordinate with P-3 aircraft, this study was limited to S-3 aircraft and helicopters. P-3 aircraft are seldom available and many parts of the ocean are not accessible to the land-based aircraft.

The basic assumption was that, even though other studies indicate a need for change in the present equipment, [13] until changes in equipment are brought about, we must manipulate our current equipment to our best advantage. In order to facilitate the most efficient operation with current equipment, we must discover the most workable layout for the equipment in the space available to it.

A. WATCH STATIONS

All descriptions of functions performed at each station will be describing only those functions normally performed at those stations. Emergency war-time situations may cause stations to be used in a manner for which they were not designed and such descriptions are not included in this study. A detailed physical description is not given but may be obtained from Ref. 13.

1. Tactical Coordinator Station (I)

a. Equipment

(1) Tactical Coordinator Console

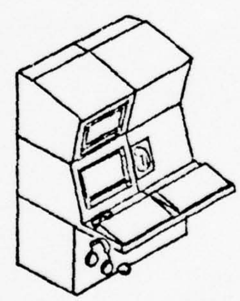


Plate (1) Tacco Console, Station I

b. Lines of Communication

(1) Interior

(a) Audio Switching Matrix (ASM) provides communication between areas of TSC and associated areas of TSC. Verbal communication to areas in TSC is a secondary method.

(2) Exterior

(a) Secure and uncovered radio circuits identical to Station III.

c. Tasks

(1) All aspects of Preflight, Inflight, and Postflight operations are included here with the exception of debrief in the Postflight phase.

2. Tactical Coordinator Station (II)

a. Equipment

(1) Tactical Coordinator Console

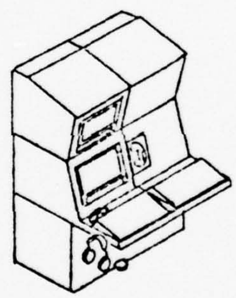


Plate (2) Tacco Console, Station II

b. Lines of Communication

(1) Interior

(a) ASM and verbal communications identical to Station I. MC system with communications to TSWO, CICO, ASAC, SURF OFF, TACO I, IC-2, STR, ADP, RAD REC 1, RAD REC 2, RAD REC 3, RAD REC 4, RAD XMT 1, RAD XMT 2, RAD XMT 3, and RAD XMT 4.

(2) Exterior

(a) Secure and uncovered radio circuits identical to Station III.

c. Tasks

(1) All aspects of Preflight, Inflight, and Postflight operations are included here with the exception of debrief in the Postflight phase.

3. Watch Officer Station (III)

a. Equipment

(1) Watch Officer Console

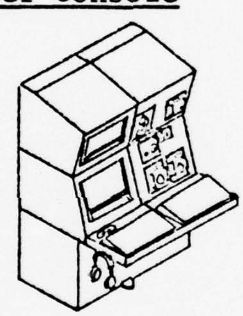


Plate (3) Watch Officer's Console, Station III

b. Lines of Communication

(1) Interior

(a) ASM and verbal communication identical to Station I. MC system with communication to Flag Officer Control Station, Pilot House, Pri-Fly, Fac Black, Central Control, Sec Conn, CICO, FICO, SURF OPS, CAPT-PILOT, SIG STA SUPV, ENG OPS, Lookout, CATCC, D & D, AIR WAR, SURF, EW, CICO, OPS OFF, CVIC, ASAC, TACCO I, TACCO II, IC-2, STR, ADP,

RAD REC 2, RAD REC 3, RAD REC 4, RAD XMT 1, RAD XMT 2, RAD XMT 3, and RAD XMT 4.

(2) Exterior

(a) Secure radio circuits as follows: Task Group Tactical, Fleet Tactical Warning, PIRAZ, Strike, SAU A, SAU B, SAU C, SSSC, SNIP, and NAVY RED.

(b) Uncovered radio circuits are as follows: Task Group Tactical, Fleet Tactical Warning, OTC SUB OPS, Beaver, SAU A, SAU B, SAU C, ASW AIR, SSSC, AND SAR Commander.

c. Tasks

(1) All aspects of Preflight, Inflight, and Postflight operations are included here with the exception of debriefing during Postflight.

4. Brief/Debrief Station (IV and V)

a. Equipment

(1) Brief/Debrief Console

(2) Television Projector

(3) Hard Copy Printer

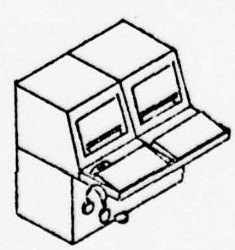


Plate (4) Brief/Debrief Console, Station IV, V

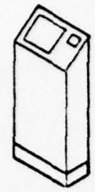


Plate (5) Hard Copy Printer

b. Lines of Communication

(1) With the exception of the hard copy printer, the above equipment is located in ready rooms so that the only line of communication is by shipboard telephone to other spaces. The hard copy printer is located in the TSC watch space so the hard copy of the briefing must be hand carried from the TSC watch space to the briefing room.

c. Tasks

(1) To carry out communication between CV-TSC personnel and aircrews during Preflight phase, and debriefing during Postflight phase.

5. <u>Automatic Data Processor (VI)</u>

a. Equipment

1. ADP Console, Recorder/Reproducer Magnetic Disk, S-3 Magnetic Tape Cabinet, High Speed Line Printer, Computer AN/UYK-20, Computer AN/UYK-7, Digital Generating Unit, Computer Univac 1640, Second Hard Copy Printer,

Teletype Keyboard and Printer, plus various maintenance equipment and spare parts.

b. Lines of Communication

(1) ASM and MC system identical to Station I and shipboard telephone.

c. Tasks

(1) To generate computer inputs so that the system operates properly.

(2) Maintenance area.

6. <u>Fast Time Analyzer</u>

a. Equipment

(1) Fast Time Analyzer Main Console

(2) Fast Time Analyzer

(3) Fast Time Analyzer Plotter

(4) Magnetic Tape Unit and Magnetic Tape Controller

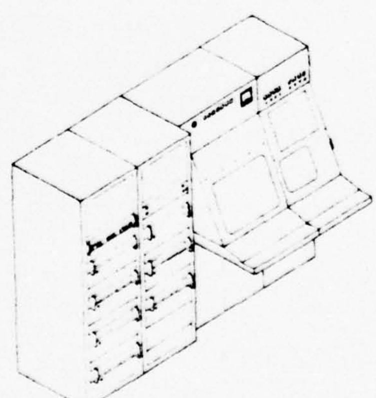


Plate (6) FTA Main Console and Analyzer

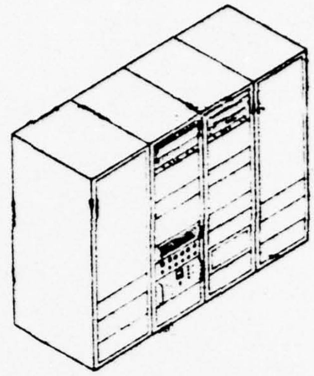


Plate (7) Magnetic Tape Unit and Magnetic Tape Controller

b. Lines of Communication

(1) Verbal communication only.

c. Tasks

(1) To display and analyze acoustic data received from S-3 cassettes and/or other tapes and to accomplish this in a real time or faster than real time, ie. an eight hour mission replayed in one hour.

7. Gram Analyzation

a. Equipment

(1) Four LOFAR gram units

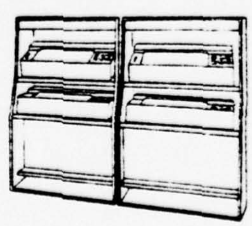


Plate (8) LOFAR Gram Units

b. Lines of Communication

(1) Verbal communication only.

c. Tasks

(1) To display and analyze acoustic data received in real time from MCJR/MCDR relay.

(2) To display and analyze acoustic data received from S-3 cassettes during the postflight process.

8. Miscellaneous Station

a. Equipment

(1) Desk

(2) Teletype Printer

Plate (9) Teletype Printer

b. Lines of Communication

(1) Verbal communications only.

c. Tasks

(1) Desk is used for displaying and assembling information.

(2) Teletype printer is used to receive intelligence information from SOSSUS stations and for communications with P-3 aircraft.

III. MISSION PROFILE

Although the TSC at times works with different types of aircraft in the air at the same time, each aircraft type has its own mission profile. Thus, adjustments must be made to handle this difference. Regardless of the particular aircraft to be supported, the chain of command within the TSC remains the same as illustrated in plate (10).

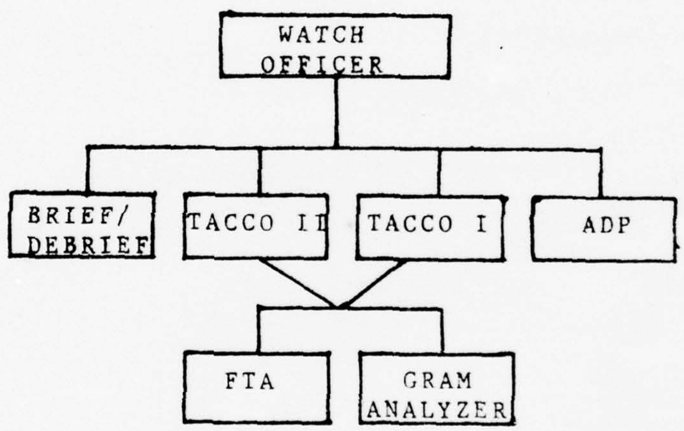


Plate (10) TSC Chain of Command

Even though TACCO I and TACCO II are considered subordinates to the watch officer, due to the similarity of the station consoles, the TACCO's may carry out all tasks given to the watch officer with the exception of communication via the MC circuits. This similar capability makes it often impossible to determine whether the task is actually being

accomplished by the watch officer or the TACCO. However, ultimate responsibility for task completion belongs to the watch officer.

A. S-3 AIRCRAFT

1. Preflight

During preflight the watch officer must insure that all equipment is activated and functioning properly. Data must be gathered from many areas of the ship and translated into a format that the system finds acceptable. This data includes such things as the carrier's own location, aircrew, mission assignment, weapons loadout, sonobuoy loadout, etc. All data must be entered on S-3 cassettes and distributed to flight crews for insertion in their aircraft. Hard copies of the briefing must be made and hand carried to the briefing room. The briefing is then conducted by the briefing officer. Plate (11) gives a link diagram.

2. Inflight

The S-3 aircraft is designed to operate entirely without outside assistance during the inflight phase and is assigned medium and long range distances from the carrier. Radio communication between the S-3 and TSC must be maintained so that as the situation alters, both the S-3 and TSC will be advised of each change. The S-3 must notify the TSC of such

events as submarine detected, weapons launched, submarines destroyed, etc. The TSC will use radio communication to inform the S-3 of such things as change of area assigned to it to be searched for submarines. Search areas for the S-3 change quite often due to intelligence reports and changes in ship's operating plans, etc. Plate (12) gives a link diagram.

3. Postflight

Upon return to the carrier, the S-3's cassettes and tapes are immediately delivered to the TSC area by designated members of the flight crew. While the debriefing officer is personally debriefing the flight crew in the ready room, the mission is being replayed in the TSC by utilizing the FTA and LOFAR grams. A two hour mission may be replayed in fifteen minutes. The mission is analyzed by TSC personnel and critiqued with the flight crew while the grams are examined for possible missed detections. Any information gathered is utilized in mission planning for the next mission via intelligence. Plate (13) gives a link diagram.

B. HELICOPTERS

1. Preflight

During preflight the watch officer must insure that all equipment is activated and functioning properly. Data

must be gathered from many areas of the ship and translated into a format that the system finds acceptable. The data includes such things as the carrier's own location, weather, aircrew, mission assignment, weapon loadout, sonobuoy loadout, etc. Hard copies of the briefing must be made and hand carried to the briefing room. The briefing is then conducted by the briefing officer. Plate (14) gives a link diagram.

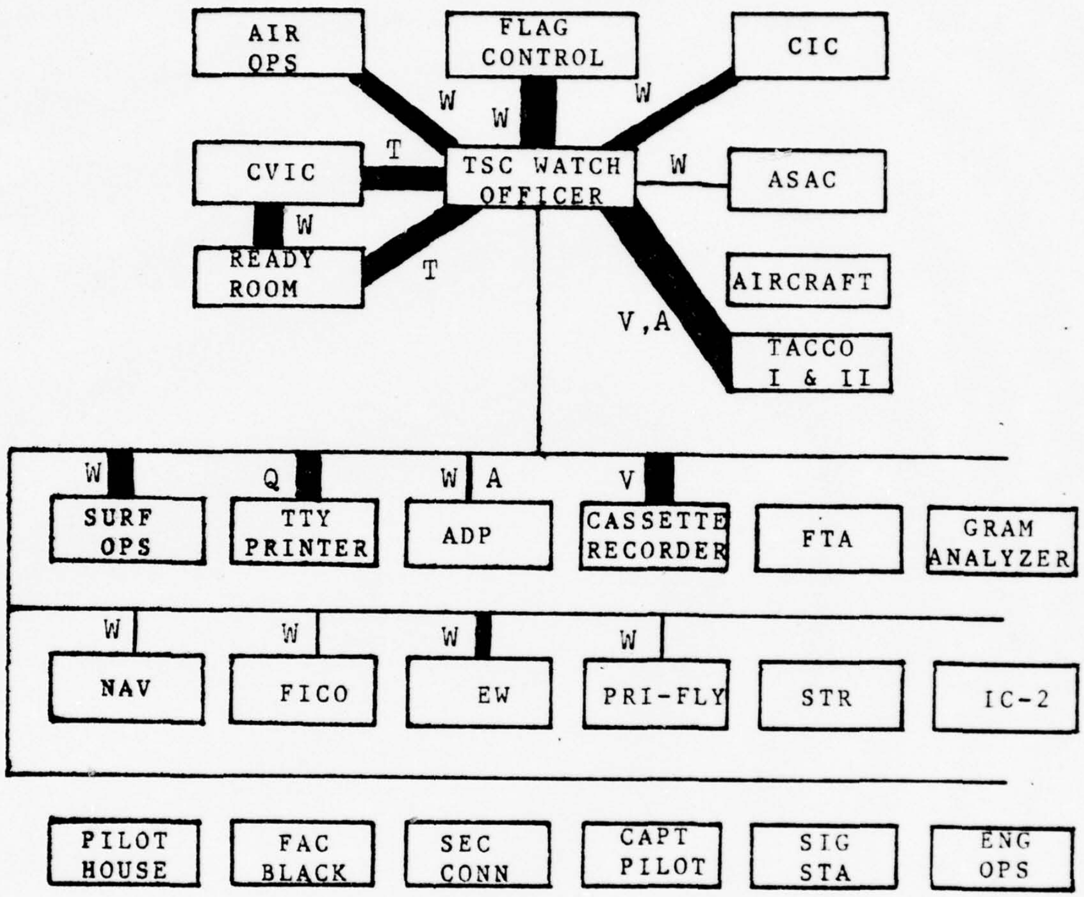
2. Inflight

The helicopter is designed to operate at a close range and must have outside assistance to perform its mission. The helicopter must maintain radio communications with the carrier for purposes of navigation control, tactical control, and acoustic processing of sonobuoys. Since the helicopter is incapable of processing its own acoustic data, the CV-TSC must maintain constant radio communications with the helicopter and have this information displayed on the LOFAR grams of the TSC. Once a target is detected by the LOFAR gram operator, notification of the detection must be relayed to the aircrew via radio communication. Other stations located within the carrier must also be notified of this detection. Plate (15) gives a link diagram.

3. Postflight

Upon return to the carrier, the members of the flight crew are debriefed by the debriefing officer. Any useful

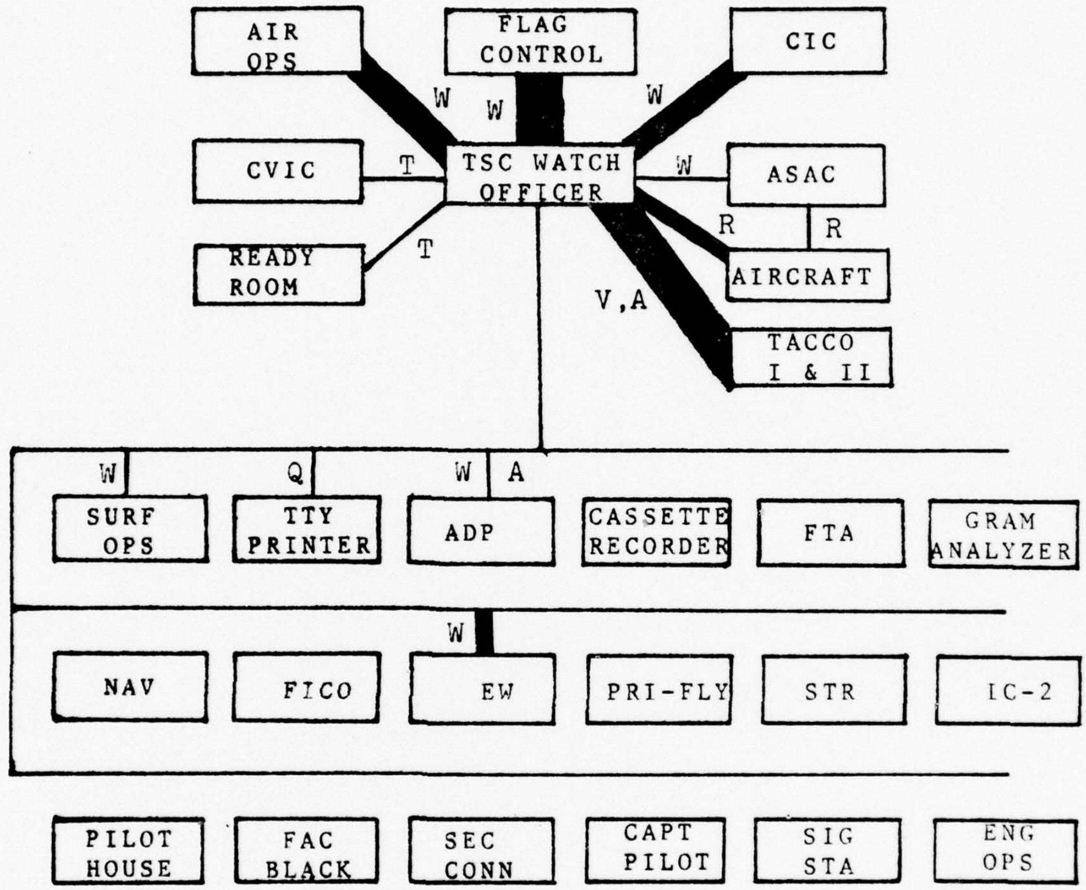
information gathered from the debriefing is entered into the system via the TSC watch officer. Plate (16) gives a link diagram.



V = Verbal
T = Telephone only
M = MC only
W = MC and Telephone

A = ASM
Q = Visual
R = Radio

Plate (11) Link Analysis of S-3 Preflight Phase. Width of Path Proportional to Frequency of Use.



V = Verbal
T = Telephone only
M = MC only
W = MC and Telephone

A = ASM
Q = Visual
R = Radio

Plate (12) Link Analysis of S-3 Inflight Phase. Width of Path Proportional to Frequency of Use.

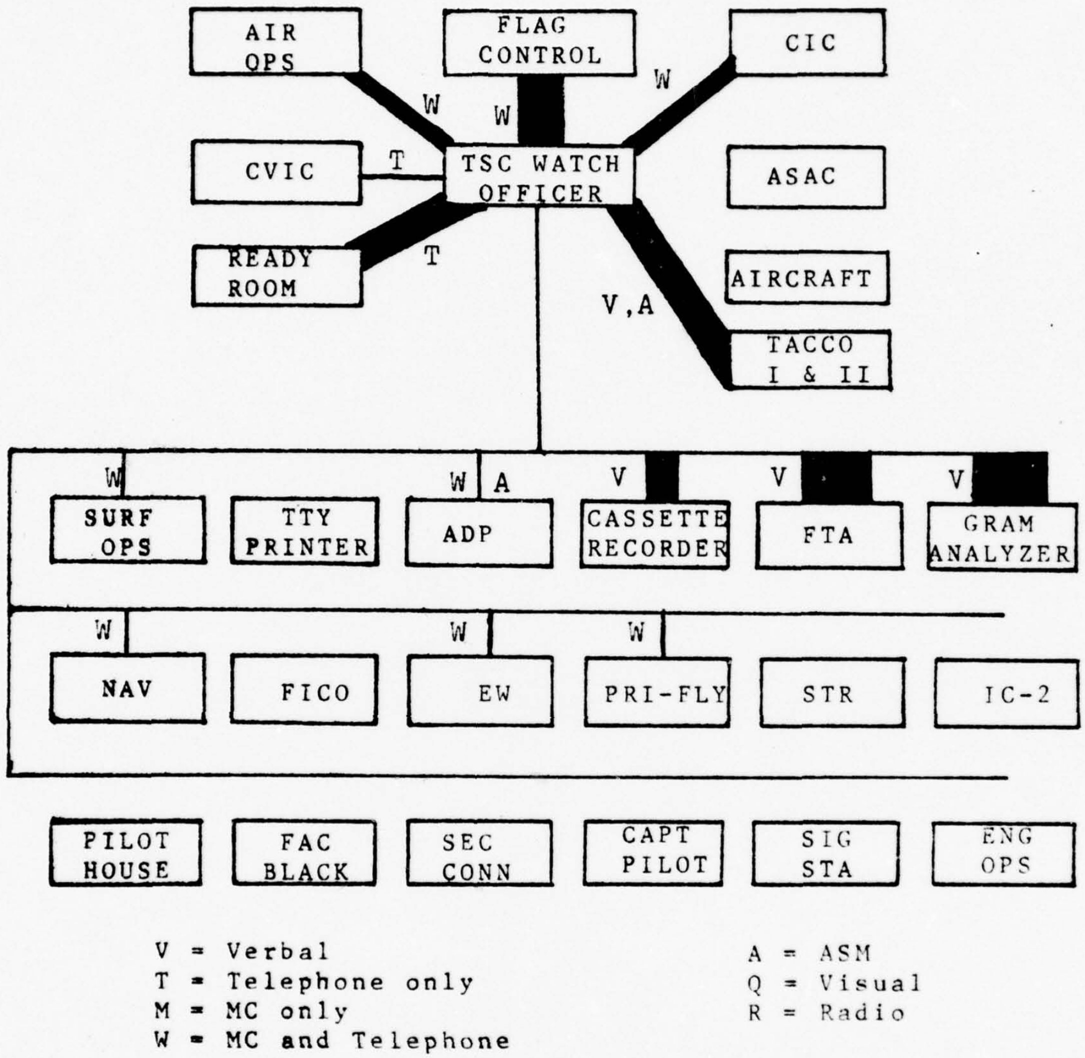
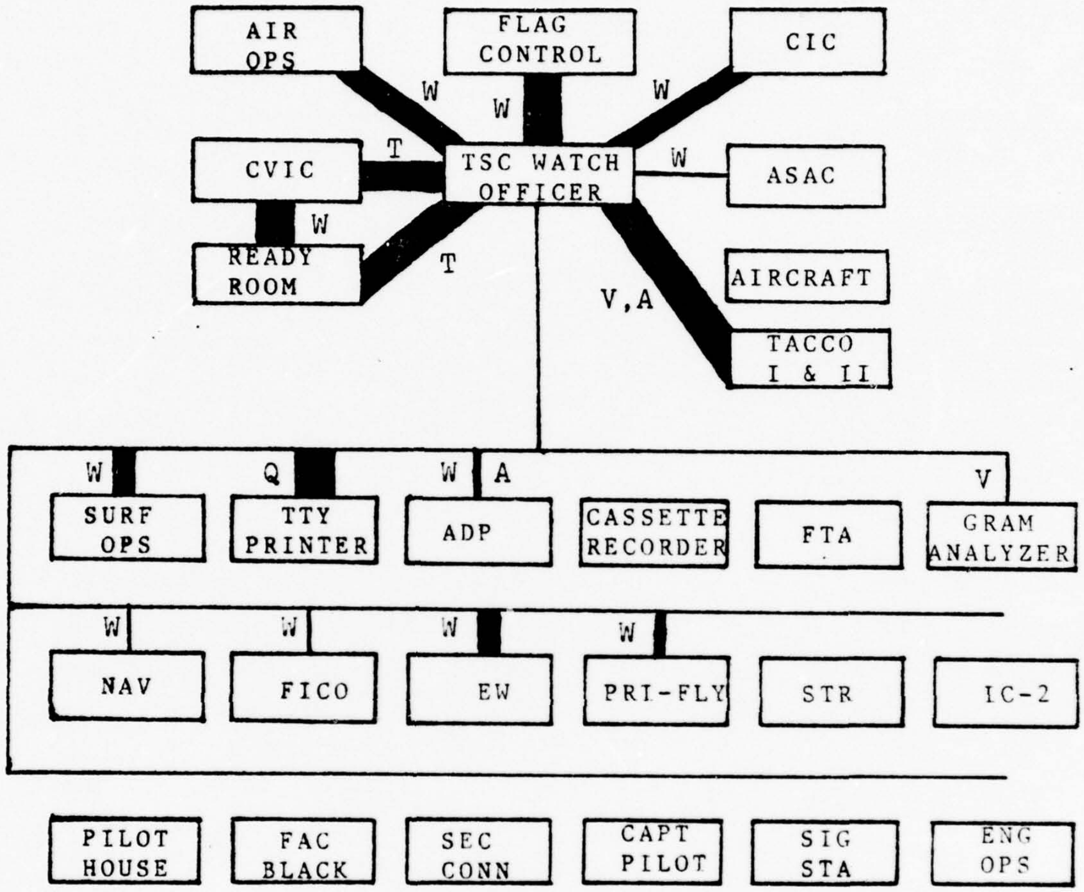


Plate (13) Link Analysis of S-3 Postflight Phase. Width of Path Proportional to Frequency of Use.



V = Verbal
T = Telephone only
M = MC only
W = MC and Telephone

A = ASM
Q = Visual
R = Radio

Plate (14) Link Analysis of Helicopter Preflight Phase. Width of Path Proportional to Frequency of Use.

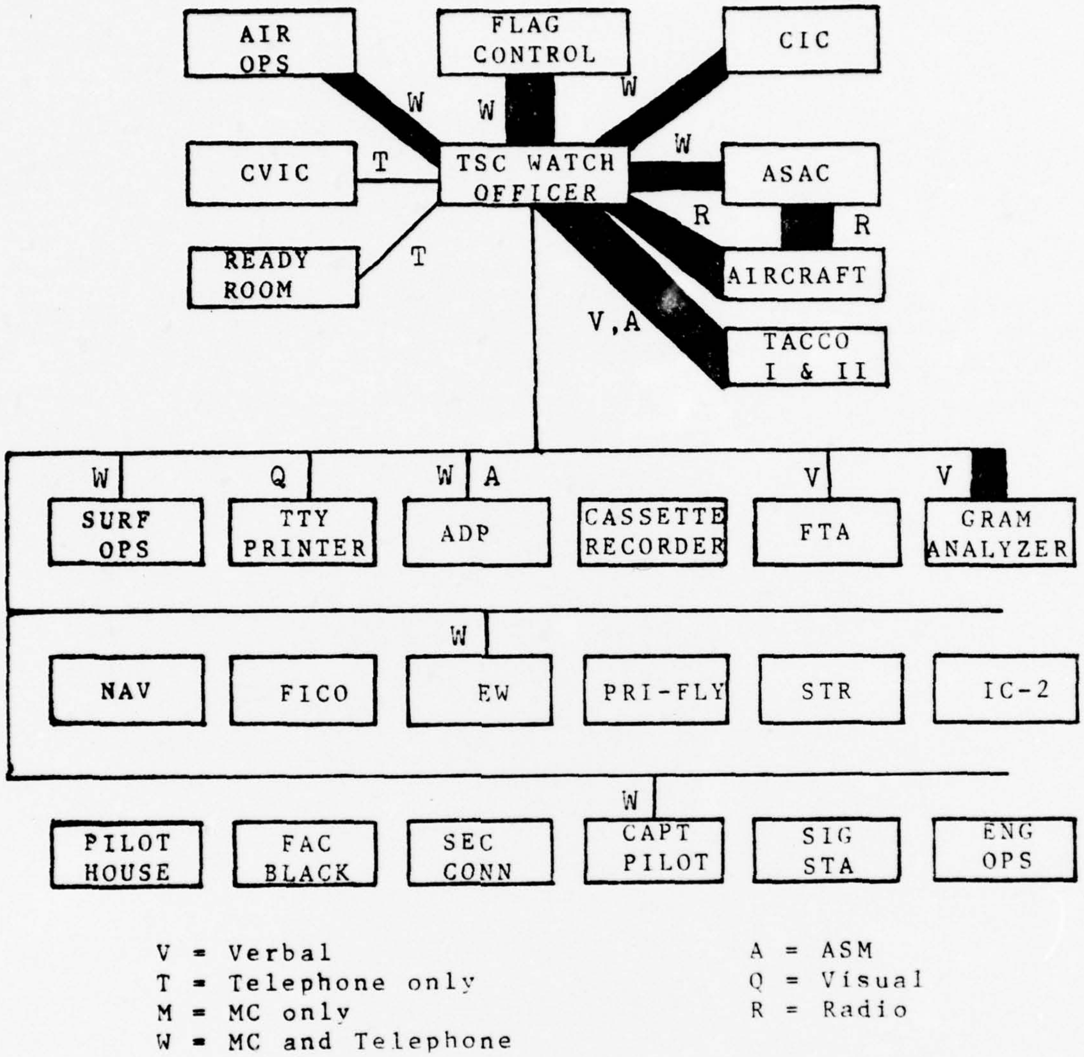


Plate (15) Link Analysis of Helicopter Inflight Phase. Width of Path Proportional to Frequency of Use.

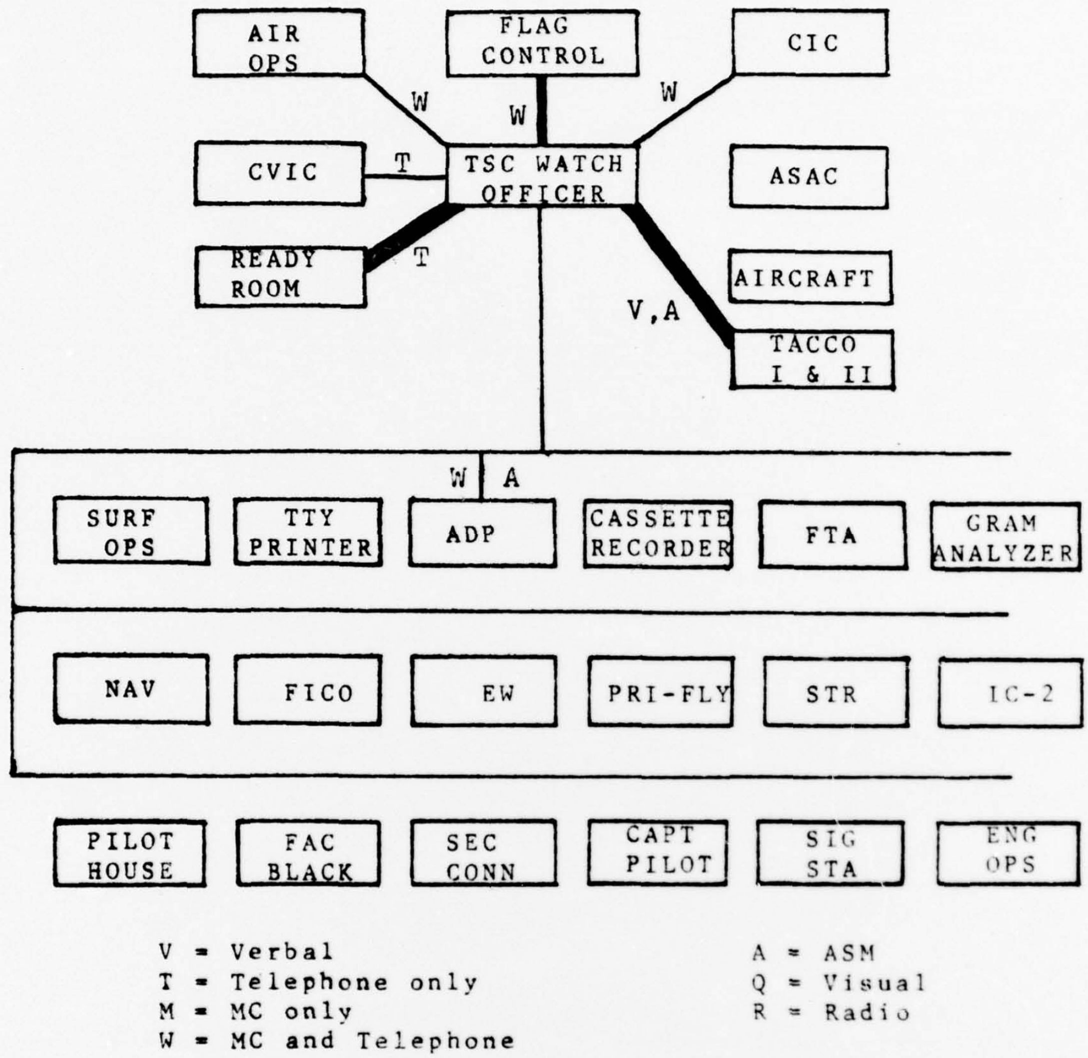


Plate (16) Link Analysis of Helicopter Postflight Phase. Width of Path Proportional to Frequency of Use.

IV. INSTALLATION DESIGN

A. PRESENT INSTALLATION DESIGN INADEQUACIES

1. Present Installation

Plate (17) shows the CV-TSC watch area as it now is aboard the USS CONSTELLATION (CV-64).

2. Personnel Flow

References 15 and 16 concur that the space necessary for a man to be able to traverse through an area is a minimum of fifteen inches. A fifteen inch space requires the man to turn sideways in order to pass through the area, but twenty-two to twenty-four inches are preferred for easier accessability. The present installation does not have this necessary space.

The space between the desk and various equipments is as follows: TTY seven inches, hard copy printer seven inches, ASM with doors open zero inches, and watch officer station six inches. Therefore, to operate the TTY or hard copy printer correctly requires movement of the desk. Access to the secure safe requires moving the desk away from the watch officer station or from the TTY and hard copy printer. Performance of maintenance on the magnetic tape controller/ASM requires movement of the desk and at times reduces the main

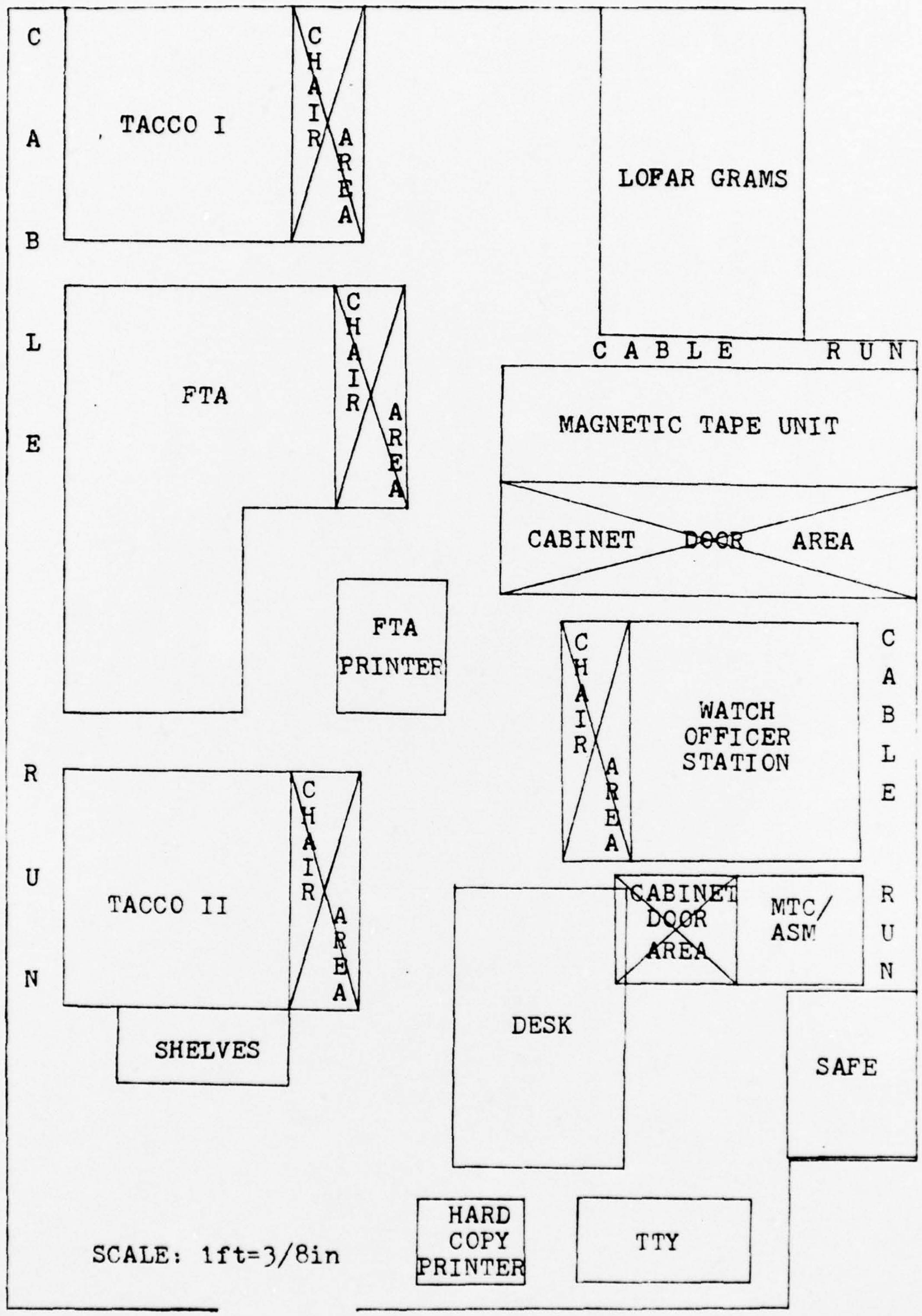


Plate (17) USS CONSTELLATION (CV-64) TSC Installation

access area to less than fifteen inches between the desk and TACCO II. The desk is continually being moved with the result that it disturbs personnel working at the desk and personnel at other stations.

The distance between the FTA plotter and magnetic tape unit with the doors open is eleven inches.

3. Communication Flow

References 9 and 14 suggest that controls, displays, and stations which operate or monitor in conjunction should be located together.

The system breaks down into several associated groups that act in conjunction.

The associated groups are as follows: Group I contains TACCO I, TACCO II, and watch officer station, Group II contains FTA, FTA plotter, magnetic tape controller/ASM, LOFAR grams, and magnetic tape unit, Group III contains the desk, TTY, Group IV contains hard copy printer, and Group V contains the secure storage area. These groups are based on frequency and importance of communication between the various stations.

The normal operation for Group I is composed of the watch officer station and one of the TACCO stations while the second TACCO station is kept in reserve, ready for use if there is a casualty in one of the other two stations. At

the present time the three stations, instead of being grouped together as a unit, are scattered so widely around the TSC watch area that using them in the course of normal operations is time consuming and inefficient. This leads to communications problems in the verbal and hand-carried areas.

In Group II, the magnetic tape controller/ASM is located away from the rest of the group and requires personnel to walk through a high population area and also forces interference with other stations to get to the area. From the LOFAR grams and FTA areas it is impossible to tell if the magnetic tape controller/ASM is operational. In order to determine this, personnel must either walk back and forth to the stations or shout back and forth to other personnel.

While operating controls on parts of the FTA, it is impossible for the operator to receive visual feedback from the LOFAR grams. Therefore two operators are required instead of one, or one person must walk back and forth between the areas if he wishes to see accurately what he is doing.

The secure storage area, which is utilized almost entirely by the TSC watch officer or TACCO's, is located in such a position that getting access to it requires moving the desk and various personnel.

The entire installation's efficiency is significantly reduced as personnel are constantly being forced to interfere

with other personnel in the course of carrying out their duties.

B. RECOMMENDED INSTALLATION DESIGN

1. Recommended Installation

Plate (18) shows the CV-TSC watch area aboard the USS CONSTELLATION (CV-64) as recommended by this study utilizing the concepts given in Refs. 3, 4, 9, 15 and 16.

2. Recommended Design Advantages

Reference 14 states "a study of the relative frequency of interaction between components, makes it possible to arrange equipment and operator positions to minimize the amount of walking or reaching or the number of contacts between the operators for transmitting information. The latter tends to <u>reduce</u> the probability of <u>human error</u>." The recommended design utilizes the close grouping concept of Ref. 9 and 14.

Throughout all phases of the TSC operation, the watch officer and the TACCO have a high frequency of interaction and communication. Taking this high frequency of communication into account, the watch officer station and TACCO II station are located side by side. TACCO I station is located in close proximity to the watch officer station in case need for its use arises. Their close proximity allows for the

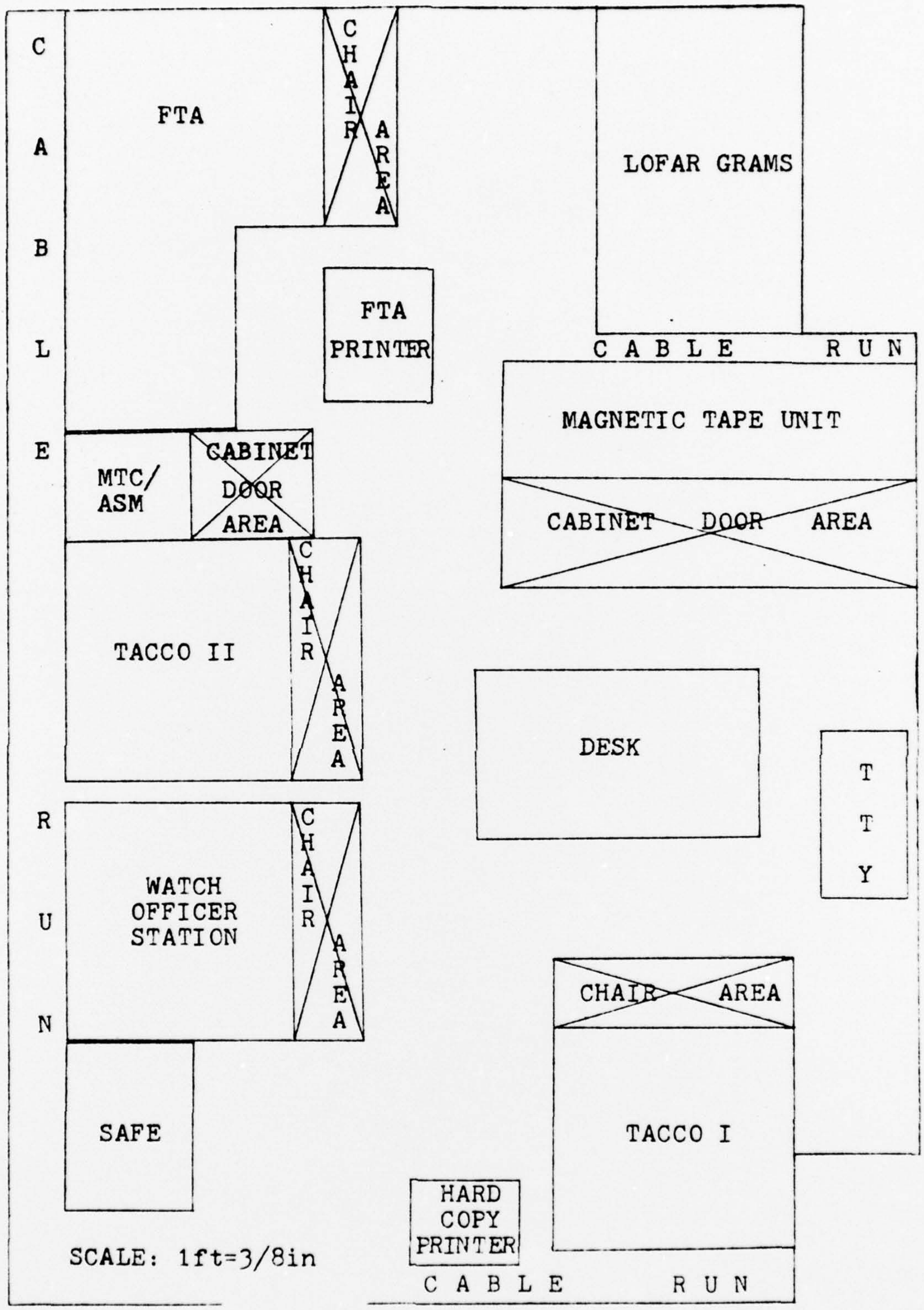


Plate (18) Recommended Design for USS CONSTELLATION (CV-64) TSC Installation

maximum use of verbal communication between the station and allows the ASM circuit to remain open for communications from other areas of the ship. Rapid, efficient, and correct processing of information is a must in ASW. If a submarine is detected by the LOFAR gram operator, then the information must be relayed quickly to the TACCO and watch officer, who in turn must evaluate and relay this information to the helicopter for attack. If this process is not done quickly, in a minimum of time, the submarine contact may be lost and the opportunity to destroy the enemy is gone. Due to the high interaction between the TACCO's and the watch officer, the grouping of them together is a requirement to reduce human error and improve efficiency in the system.

The analysis section of the TSC, made up of the LOFAR grams, FTA, FTA plotter, magnetic tape unit, and magnetic tape controller/ASM, have been grouped together for several reasons.

One reason is the need for feedback to operators from manipulation of controls. The magnetic tape unit's controls and the feedback from the unit for operators is all located on the front of the unit and there is adequate room in this area for the personnel assigned to the station. When operating the MTC/ASM, several of the controls on its front panel, control some of the functions of the FTA and the LOFAR grams. Both the FTA and LOFAR grams can now be verified as operating

properly without leaving the operating controls located on the front of the MTC/ASM. The FTA plotter remains in close proximity to the FTA because the FTA controls the plotter and provides operating personnel the immediate opportunity to verify that the plotter is functioning properly. The present design now has the FTA and LOFAR grams located in such a position that the operator of the FTA cannot receive immediate visual feedback from the LOFAR grams while operating the controls on the FTA. This frequent verification of the frequencies displayed on the LOFAR gram and the FTA can be easily accomplished without leaving the controls located on the front of the FTA with the recommended design. This close proximity and immediate feedback tend to reduce human error and increase efficiency in the operation of the CV-TSC.

A second reason for the grouping of the analysis section is that the actual means necessary for the detection of the submarine are located in one area. This enables the watch officer and TACCO to expect to receive the critical notification of a submarine detection from one general location.

Therefore, the recommended installation not only decreases the physical separation between the stations but also lowers the frequency of communications required between

the stations. The recommended installation efficiently organizes the communication flow into the basic flow required, that of detection, notification of detection to higher command and to the attacking unit.

Traffic flow of personnel in the recommended design will not only be reduced but that flow that is still required will be much easier and safer.

The hard copy unit remains located near the door, because the briefing officer is the one who utilizes it, by making copies and delivering them to the briefing rooms. Part of the controls of the hard copy printer are located on the watch officer station, TACCO I, and TACCO II station. With these three stations located near the hard copy printer it reduces the movement required of the briefing officer in the TSC to obtain a copy from the hard copy printer.

As previously mentioned in the area of communication flow the recommended analysis area with its immediate feedback reduces the necessity for personnel to continually walk back and forth from such units as the FTA, LOFAR grams, and MTC/ASM. The nature of the watch officer station requires contact with many areas and often times the communication is done in person by personnel entering the TSC area. Therefore, the recommended design has moved the watch officer

station to close proximity with the door to reduce the traffic flow throughout the rest of the TSC area.

Although traffic flow of personnel will be greatly reduced in the recommended design due to the modular technique of grouping, personnel will still find it necessary to move around in the watch area to facilitate carrying out the mission. Therefore, all traffic ways have been increased to a minimum of fifteen inches with twenty-four inches allowed for the major traveled areas. [15, 16]

The widening of the traffic ways reduces interference with personnel and will tend to reduce human error. However, the most significant alteration of the recommended design change is in the area of safety. During normal operation and while performing maintenance and/or casualty repair, equipment doors and modules are required to be open with the inherent exposure of electrical circuits. The significant decrease in personnel traffic flow, and the greater area allowed for this necessary flow, significantly reduces the probability of damage to exposed equipment, and/or injury or accidental death to operating or maintenance personnel, as a result of coming in contact with energized electrical circuits.

Overall the new installation design lends itself to a lower level of human error and more efficient flow with regards to communication and personnel.

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